

8

SYSTEMS ENGINEERING AND SUPPORTABILITY ANALYSES

The success of a logistics program hinges on how the readiness and supportability characteristics are designed into the system.

Key concept

8.1 INTRODUCTION

The purpose of this chapter is to address the role of logistics as an element in the Systems Engineering (SE) process. Only selected highlights of the SE process, i.e., those that clarify the linkage between logistics and SE, are presented herein.

The SE process is used to translate operational needs and requirements into a system solution that includes the design, manufacturing, test and evaluation, and support processes and products. A major goal of SE is the achievement of a proper balance among performance (including readiness and supportability), risk, cost, and schedule. This goal is sought by employing the following top-down iterative steps that define the SE process: requirements analysis, functional analysis and allocation, design synthesis and verification, and system analysis and control.

The readiness and supportability characteristics of a system must be included in the design in during the early phases, i.e., Concept Exploration (CE) and Program Definition and Risk Reduction (PDRR), while the system design is in its formative stages and trade-offs are most easily accomplished. Thereafter, these characteristics must be reevaluated continually through the life of the program, considering, among other things, the opportunity for technology insertion to enhance readiness and supportability. The optimal way to achieve this result is to establish a rigorous formal relationship at the onset of system development and between the logistics system design effort and the SE process. Readiness and supportability characteristics must be considered in performing functional and tradeoff analyses, and the SE process provides the framework for enabling the effective acquisition of a supportable system.

System maintainability and supportability goals are best achieved by addressing support requirements as elements of the SE tradeoff and decision criteria. A balanced integration of logistics considerations in the SE process achieves the following objectives:

- produces readiness objectives that will be challenging but attainable,

- identifies realistic reliability and maintainability requirements to achieve these objectives,
- identifies support and manpower drivers, and
- assigns appropriate priority to logistics element requirements in system design tradeoffs.

Four summary points are worthy of mention as a foundation for the logistics/SE linkage:

The SE process is iterative in nature, entailing four elements: requirements analysis; functional analysis/allocation; synthesis; and overall, systems analysis and control. Feedback loops between each of the first three elements are an essential part of the process. Of these, the feedback loop between the synthesis element and the design requirements element represents the verification process, involving testing and evaluation, audits, and design reviews to provide appropriate feedback regarding the attainment of system requirements. Figure 8-1 illustrates the iterative nature of this process.

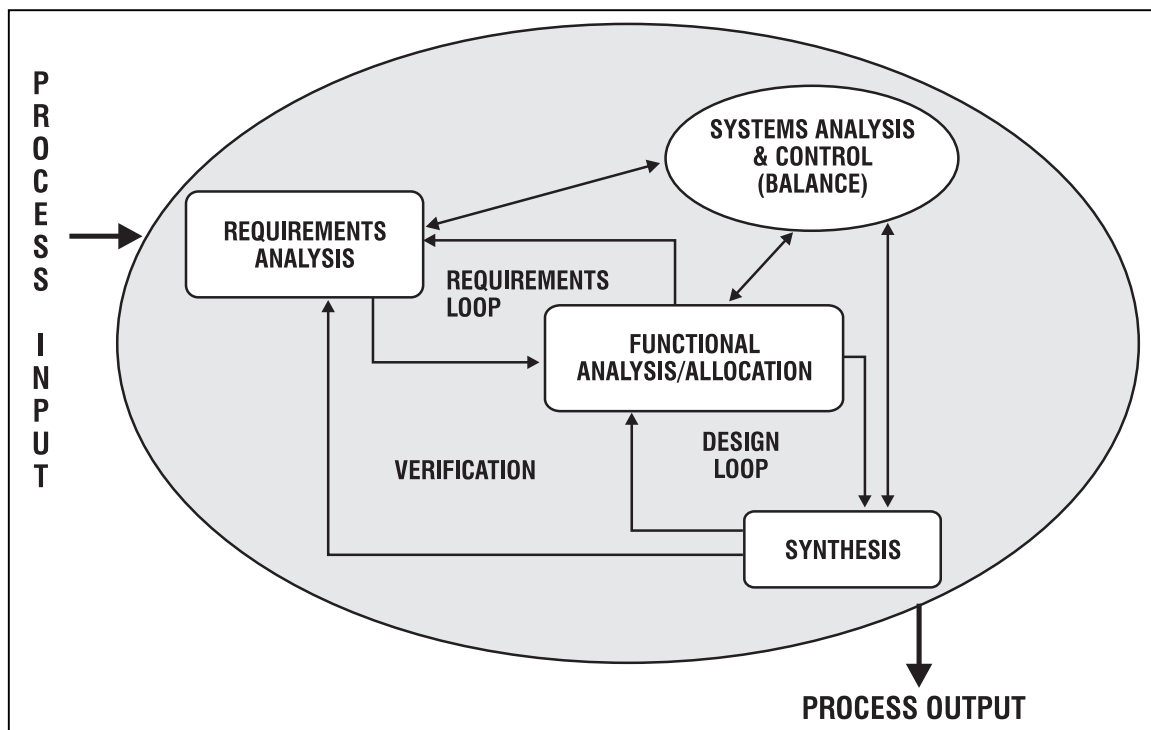


Figure 8-1: The Systems Engineering Process

- Further, SE is applied repetitively within each phase of the acquisition process. A progressive change in the central focus of SE takes place as the development progresses, starting with system-level considerations in the early phases, subsequently overlaid with subsystem considerations (which become the focus in the mid-phases), and followed later by component considerations as the design matures.

- There are many “elements” to be considered in the SE process. Some, like design engineering, come readily to mind when SE is mentioned. Others, like environmental compatibility, electromagnetic compatibility, vulnerability, and commonality, are elements that must be considered throughout the SE process; but they tend to require more SE Integrated Product Team (IPT) effort to keep them in the foreground during tradeoffs, planning, and evaluation. A term has been coined to account for many of these items with names ending in “ility” – the “Ilities.” Figure 8-2 combines the many “roots and limbs” of SE into a systemic entity.
- Because logistics considerations are an element of SE, they must be integrated into the SE process from the onset. Supportability and readiness analyses are essential in each stage of the process. A word of caution is necessary, however, regarding the relationship between the design engineer and the logistician. At times, design considerations are likely to be in conflict with the supportability and maintainability concerns of the logistician. In such cases trade studies can be used to identify the proper resolution of such conflicts. When conflicts do occur, it is important that readiness and supportability issues be given the same importance as program schedule and performance. To say that logistics and supportability analyses are a part of SE does not imply that the logistics voice is subservient to the engineering voice on the integrated team or in the project office. Organizationally, the logistician must be a principal player in the development process.

8.1.1 Design Considerations

Many considerations influence system design, and chief among them are the following:

- cost;
- manufacturing/production;
- quality;
- open-system design;
- logistics/supportability;
- reliability, maintainability;
- environment and safety;
- human systems integration; and
- interoperability

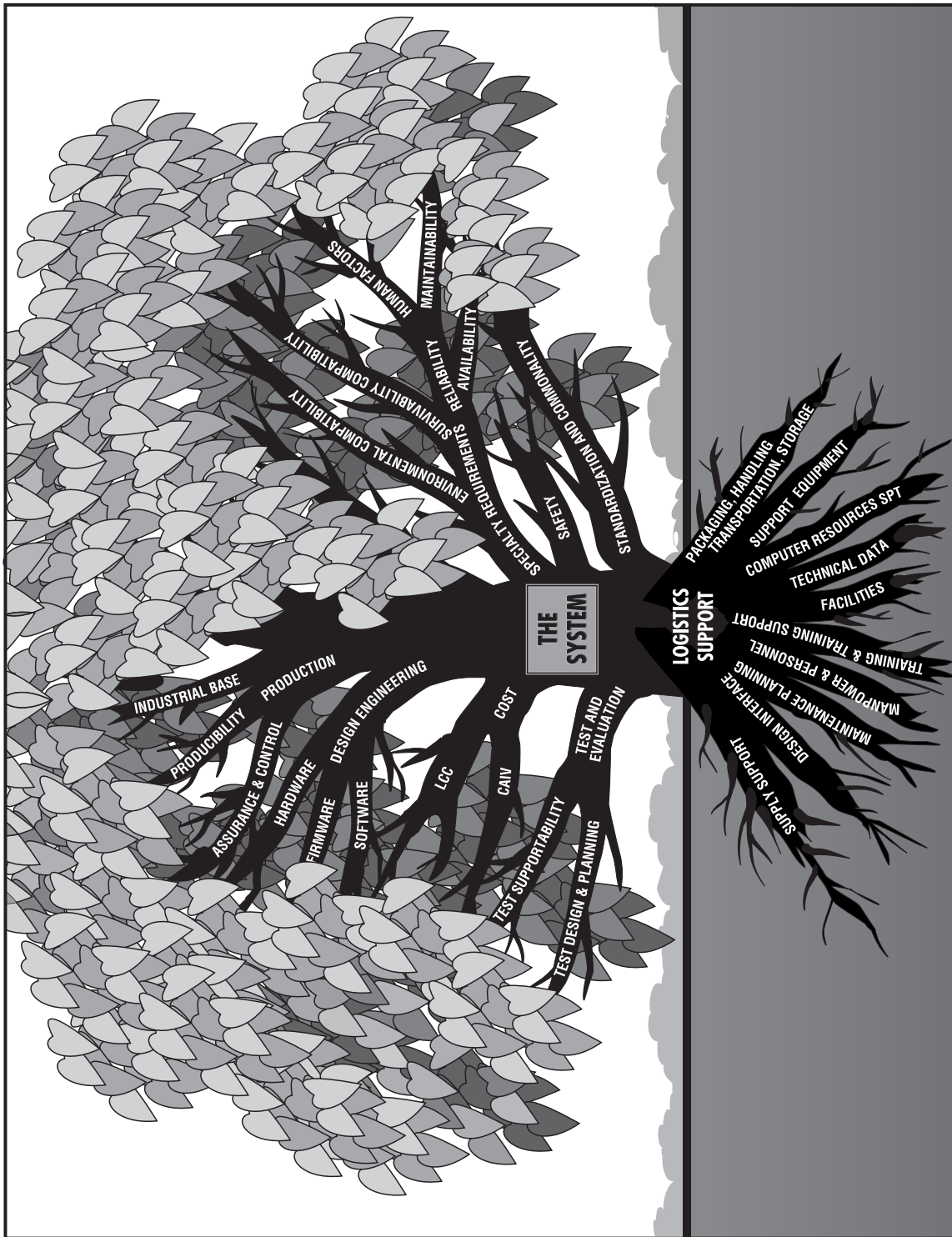


Figure 8-2: Systems Engineering and the "Iilities"

This Chapter will concentrate on three of the topics, i.e., open system design, supportability, and reliability/maintainability. These topics deserve emphasis because of their close association with activities of the Logistics Manager (LM) and, in the case of open system design, because of current DoD policy emphasis.

8.2 OPEN SYSTEMS DESIGN

The following material is presented at the onset of the SE Chapter in recognition of the importance of open systems architecture in reducing system life-cycle cost. The system architecture should be addressed early in a program, as part of the SE process, to maximize the number of potential solutions and, thereby, help reduce program cost. By developing the architecture early in a program, the specific technology used in its implementation can then be chosen as late as possible. The following material has been adapted from the “Open Systems Joint Task Force” section of the *DoD Deskbook*.

8.2.1 Discussion

The **open system approach entails a plan structured to facilitate the use of widely accepted standard products** from multiple suppliers. In instances where system architecture is defined by the specifications and standards used in the private sector, DoD can be one of many customers and leverage the benefits of the commercial marketplace. The open system approach can have a profound effect on the life-cycle cost of a system as discussed below.

- With its implementation, program managers have access to alternative sources for the key subsystems and components to construct DoD systems.
- DoD investment early in the life cycle is reduced, since at least some of the required subsystems or components are likely to be available.
- Production sources can be competitively selected from multiple competitors.
- The system design flexibility, inherent in the open-system approach, and the more widespread availability of conforming commercial products, mitigates potential problems associated with a diminishing defense-dependent manufacturing base.
- Standards-based architecture facilitates upgrades by incremental technology insertion, rather than by large-scale system redesign.

The open system approach is an integrated technical and business strategy that defines key interfaces for the system (or piece of equipment) being developed. Interfaces generally are best defined by formal consensus (adopted by recognized industry standards bodies) on specifications and standards. However, commonly accepted specifications and standards (both company proprietary and nonproprietary) are also acceptable if they fa-

cilitate utilization of multiple suppliers. The use of de facto specifications and standards takes advantage of the fact that firms, particularly those in the commercial arena, frequently develop hardware, software, and systems standards for the design and fabrication of computing, telecommunications, display, sensing, and signal processing systems. Whether interfaces are described by consensus or de facto standards the benefits only accrue if products from multiple sources are economically possible. Although the most common emphasis is on electronic systems, the open system approach is widely applicable, from fasteners and light bulbs to jet engines.

An effective open-system architecture will rely on physical modularity and functional partitioning of both hardware and software. Physical modularity and functional partitioning should be aligned to facilitate the replacement of specific subsystems and components without impacting others. The subsystems and components described by the system design should be consistent with the system repairable level. Subsystems and components below the repairable level will normally not be under government configuration control. Therefore, repairs below the repairable level, if required, will be by the supplier. If the hardware and software is effectively partitioned, processing hardware can be replaced with new technology without modifying application software. In addition, application software can be modified without necessitating hardware changes.

Open-system interfaces must be managed more rigorously than in previous practice. An interface specification or standard is inherently a performance standard, is used as such by industry, and must be recognized as such in DoD. System partitions must not violate the interface, unilaterally extend it, or define it so that it is no longer compliant with the standard. At the start of production, the open-system requirements are published, thus identifying the market opportunities for suppliers.

8.2.1.1 Military Requirements. The open-system approach facilitates the use of lower cost, high-performance subsystems and components, mostly built to commercial specifications and standards within the overall system. The open-system approach does not imply that only consumer-grade products should be used. However, some commercial environments are as demanding as military environments, and commercial products that function in these environments will also function in the military environment. In any case, all open-system designs still must meet military requirements.

8.2.1.2 Legacy Systems. The application of the open-system approach to legacy systems is less obvious but still beneficial. Legacy systems usually have size, space, power, cooling, and shape factor constraints. For these systems, the open system approach can provide Form-Fit-Function Interface (F3I) solutions within existing packaging, power, and environmental constraints. In such cases the open-system solution frequently requires less system resources by using newer, more efficient technologies. The open-system approach is similar to F3I except that the open-system approach emphasizes choosing interfaces that are broadly accepted in the marketplace to allow for as many suppliers as possible over the long term.

8.2.1.3 A Smart Business Practice. The open-system approach is a new way of doing business and an important part of acquisition reform. More importantly, the open-system approach is a smart way to do business. Hard pressed to maintain the superiority of U.S. military systems within severe budget constraints, DoD program managers need the flexibility of open system to leverage the creativity and competitive pressures of the commercial marketplace. Program managers should ask this question of any proposed design solution: “What provisions have been made to ensure that the widest range of suppliers will have the opportunity to offer their products throughout the program life cycle?”

8.2.2 Example Applications

Examples of open-system applications are such initiatives as the rapid prototyping of application-specific signal processors (RASSP) at the Defense Advanced Research Projects Agency (DARPA) and the F-16 Falcon modular. In addition, the F-22 aircraft (formerly the JAST program) is coordinating its technology investments with industry and academia and other Defense Department science and technology organizations. The F-22 is evolving and demonstrating an open-system architecture, consistent with the new acquisition policies and practices. Another example is the Information Technology Standards Integrated Bulletin Board System (ITSI BBS).

8.2.3 Tools

DoD Technical Architecture Framework for Information Management (TAFIM), Version 2.0, 30 June 1994, is a proven tool for information management. See the information provided below.

8.2.4 POC/Reference

- Office of the Under Secretary of Defense for Acquisition and Technology (USD(A&T))/DTSE&E, tel: 703-695-2300.
- Service Acquisition Executives.
- Director, OSJTF, tel: 703-578-6160/6568 or Home Page — <http://www.acq.osd.mil/osjtf/>
- DoD 5000.2-R, paragraph 4.3.4.
- USD(A&T) memo of 10 July 1996, Subj: Open Systems Acquisition of Weapons Systems (*Deskbook*) and resulting Service Acquisition Executive's plans for open-system approach for acquired systems.
- DoD Technical Architecture Framework for Information Management (TAFIM), Version 2.0, 30 June 1994, tel: 703-696-1750 or *Deskbook*.
- ITSI BBS Modernization Project (webmaster@itsi.disa.mil), tel: 703-735-8338 or DSN 653-8338

8.3 SUPPORTABILITY ANALYSES

Supportability factors must be considered in an organized manner throughout design and/or planning actions for the system being acquired and for each applicable logistics support element as well. To reiterate, logistics and supportability analyses must be integrated with and be a part of the SE process. In the past this frequently was not the case. Supportability analyses were often accomplished in a nonintegrated fashion, producing reports and recommendations with limited impact on design. Only by including logistics considerations in the design tradeoffs within the SE process and throughout the development cycle can the program achieve its operational goals at the lowest life-cycle cost.

Supportability analyses, when conducted within the SE process, form the basis for decisions on the scope and level of logistics support; and, of equal importance, they lead to performance requirements in the system specification and thus influence design considerations. The analyses, like the SE process, are ongoing throughout the development cycle in iterative fashion. The initial analyses should focus on the relationships of the evolving operational and readiness requirements, planned support structures, and comparisons with existing force structure and support posture. Supportability analyses can include any number of tools, practices, or techniques, many of which are described in Section 8.5 below. The following items are examples of the types of analyses that might be performed to provide appropriate inputs to an integrated Operational Requirements Document (ORD), which reflects an operational and support concept that the user finds acceptable.

8.3.1 Logistics Strategy

The logistics strategy identifies the logistics management structure and authority; what supportability analyses and verification activities are planned; who will be responsible for each activity; and how the results of each activity will be used. There is no standard format for the plan. It should be tailored for each program and should be part of the Systems Engineering Management Plan (SEMP).

8.3.2 Use Study

The use study defines the intended use of the system/component and the operational and support environments of that system/component. Quantitative support factors, such as operational availability (Ao), transportation modes/times, allowable maintenance periods, and environmental requirements (including hazardous materials, hazardous wastes, and other pollutants), are identified. These data are then incorporated into the ORD as appropriate. The use study should include consideration of the following items:

- planned deployment scenarios,
- transportability requirements,
- mission frequency and duration,

- human factors (system complexities and the supportability implications),
- anticipated service life, and
- standardization and interoperability.

8.3.3 Analysis of Comparative Systems

This analysis strives to: 1) define a sound analytical foundation for projecting a new system design and related supportability features, 2) identify aspects that need improvements over those in existing systems, and 3) identify those features that will likely drive cost, support, and readiness of the new system.

8.3.4 Evaluation of Technological Approaches/Opportunities

The purpose of this analysis is to identify technological advancements and state-of-the-art design approaches that offer opportunities to achieve new system support improvements. Use of available technological approaches is emphasized to improve upon projected safety, cost, support, and readiness values; to reduce a new system's environmental impact; and to resolve qualitative support problems.

8.3.5 Postproduction Support

The Postproduction supportability analysis should identify items that are single/dual source or those for which the government cannot obtain data rights. The related plan of action to alleviate projected problem areas should consider organic support capability, production line buy-out, or contractor logistics support agreements.

8.4 SYSTEMS ANALYSIS AND CONTROL

Six major activities and tools are used in systems analysis and control. They are:

- tradeoff studies,
- configuration management,
- data management,
- risk management,
- metrics, and
- technical reviews.

Only the first two activities will be discussed in the Chapter.

8.5 TRADEOFF STUDIES

Desirable and practical tradeoffs among requirements, technical objectives, design, program schedule, functional and performance requirements, and life-cycle costs must be identified and conducted throughout the development process.

8.5.1 Requirements Analysis Tradeoff Studies

The performing activity needs to conduct requirements analysis tradeoff studies to establish alternative performance and functional requirements to both resolve conflicts with and satisfy user requirements. Of primary importance in establishing support alternatives is the following guidance in DoD 5000.2-R, which gives precedence to contractor-provided logistics support in many situations:

”It is DoD policy to retain limited organic core depot maintenance capability to meet essential wartime surge demands, promote competition, and sustain institutional expertise. Support concepts for new and modified systems shall maximize the use of contractor-provided, long-term, total life-cycle logistics support that combines depot-level maintenance along with wholesale and selected retail materiel management functions. Life-cycle costs and use of existing capabilities, particularly while the system is in production, shall play a key role in the overall selection process. Other than stated above, and with an appropriate waiver, DoD organizations may be used as substitutes for contractor-provided logistics support, such as when contractors are unwilling to perform support, or where there is a clear, well-documented cost advantage. The PM shall provide for long-term access to data required for competitive sourcing of systems support. The waiver to use DoD organizations must be approved by the MDA.”

When considering alternative systems or alternative support concepts, the following items are representative of appropriate comparison criteria:

- life-cycle cost comparisons,
- diagnostic characteristics (e.g., Built-in-Test (BIT)),
- energy characteristics,
- battle damage repair characteristics,
- transportability characteristics, and
- facilities requirements.

8.5.1.1 Supportability Factors. DoD 5000.2-R states that: “Supportability factors are integral elements of program performance specifications. However, support requirements are not to be stated as distinct logistics elements, but instead as performance requirements that relate to a system’s operational effectiveness, operational suitability, and life-cycle cost reduction.” The following items are examples of supportability issues upon which specific objectives can be based:

- operations and maintenance personnel and staff-hour constraints,
- personnel skill level constraints,
- life-cycle and Operations and Support (O&S) cost constraints,
- target percentages of system failures correctable at each maintenance level,
- mean down time in the operational environment,
- turn-around time in the operational environment,
- standardization and interoperability requirements,
- built-in-fault isolation capability, and
- transportability requirements (identification of conveyances on which the system and its components are transportable).

8.6 CONFIGURATION MANAGEMENT

Configuration Management (CM) is a defined process applying sound business practices to manage the configuration of defense materiel items, their defining technical data, and supporting digital data files. It involves interaction among government and contractor program functions such as SE, design engineering, logistics, test, contracting, and manufacturing. It is best accomplished in an IPT environment consistent with the program infrastructure and concept of operations. There are four distinct functions to configuration management: configuration identification, configuration control, configuration status accounting, and configuration audits.

8.6.1 Configuration Identification

Configuration identification is the identification of documents comprising the configuration baselines for the system and lower-level items (including logistics support elements) and identifiers for those items and documents. When thus identified, an item is known as a configuration item (CI).

8.6.2 Configuration Control

The configuration control process manages the current configuration baseline that results from the configuration identification process. The types and levels of documentation subject to government configuration control authority are defined in pertinent contracts. At an agreed to point in the development process, the government generally accepts configuration control responsibilities and establishes a configuration control board (CCB). Requests for engineering changes are received from government technical, operational, and contract functions; and requests for Engineering Change Proposals (ECPs) are sent to the contractors. Additionally, ECPs and requests for deviations are received from contractors. After disciplined assessment of impact, cost, and risk by the CCB, approval of beneficial changes and the necessary authorization and direction for change implementation by contractors are provided to contractors through the contractual process and to affected government activities through appropriate channels.

Under current acquisition reform initiatives, numerous system support functions will be carried out by industry under contract. In some cases total contractor configuration management, including configuration control, is a distinct possibility. In most cases, however, the government will retain the configuration control function.

A CCB is typically staffed with the IPT responsible for the item, which means the LM will be a part of the team. Government CCBs typically review proposed changes that impact the item's performance requirements only. Conversely, the contractor's change control authority typically evaluates changes that impact the design solution to the item's performance requirements and do not impact the performance requirements.

8.6.3 Configuration Status Accounting

The heart of Configuration Status Accounting (CSA) is a transaction database fed by the transactions that take place under other CM processes. It provides visibility into status and configuration information concerning the product and its documentation. In essence, it provides a track of configuration documentation changes, i.e., the configuration history, and documents the configuration of CIs. With the onset of the DoD initiative to gain total asset visibility, the CSA database will likely be interconnected with the network that provides total asset visibility.

8.6.4 Configuration Verification and Audit

Configuration verification and audit uses each of the following data types at appropriate points in the development cycle:

- schedule information from status accounting,
- configuration documentation for configuration identification,
- the results of product testing,

- the physical hardware or software product or its representation,
- manufacturing instructions, and
- the software engineering environment.

These data are used to verify that the product's performance requirements have been achieved by the product design, and the product design has been accurately documented in the configuration documentation. The process also includes verifying the incorporation of approved engineering changes.

Configuration verification should be an imbedded function of the contractor's process for creating and modifying the product. Process validation by the government in lieu of physical inspection may be appropriate. Successful completion of verification and audit activities results in a verified product and documentation set that may be confidently considered a product baseline, as well as a validated process that will maintain the continuing consistency of product to documentation. MIL-HDBK-61 contains guidelines for conduction configuration audits.

8.7 SUPPORTABILITY ANALYSES

The contractor necessarily performs many supportability analyses; and, thus, it is important that the requirement for analysis reports be clearly addressed in contractual terms. With the advent of acquisition reform, a performance specification (MIL-PRF-49506, Logistics Management Information) has been developed and issued to assist in this regard. It addresses in broad terms each of the following example analyses, which roughly parallel the logistics elements discussed in Chapter 7: maintenance planning; repair analysis; support and test equipment; manpower, personnel, and training; facilities; packaging, handling, storage, and transportation; and postproduction support. Further amplification is provided in the performance specification. However, these topics are presented only as examples of useful support information that DoD managers may want to require from a contractor and are not all-inclusive or exclusive.

A worksheet format for supportability analysis summaries is provided in the specification. Figure 8-3 is a representation of that format. Note that it has a space to be filled in by the DoD manager to indicate what data are required in a specified analysis report to be included in the LMI specification. Another space is provided to identify those data elements not included in the LMI specification. A separate worksheet would be required for each analysis addressed in the contract. In the following section, several types of supportability analyses are discussed.

**MIL-PRF-49506
APPENDIX A**

Page ____ of ____

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Figure 8-3: Worksheet 1, Supportability Analysis Summaries

8.7.1 Reliability, Maintainability, and Availability (R,M&A) Analyses

The paragraphs that follow in this section discuss analyses that contribute to R,M&A. Supportability analyses play a key role in planning, designing, and fielding a reliable and maintainable system. In organizing this Guide, Chapter 10 has been devoted to the topic of reliability and maintainability. However, the sections that follow are more appropriately placed in this Chapter dealing with SE.

8.7.1.1 Definitions.

- **Reliability** is the probability that an item will perform its intended functions for a specified period under stated conditions. Reliability can be further broken down into mission reliability and logistics reliability:
 - **Mission reliability** is the probability that a system will perform mission-essential functions for a period of time under the conditions stated in the mission profile. Measures of mission reliability include only those incidents affecting mission accomplishment.
 - **Logistics reliability** is the probability that no corrective maintenance or unscheduled supply demand will occur following the completion of a specified mission profile.
- **Maintainability** is the probability that an item will conform to specified conditions within a given period when corrective or preventive action is performed in accordance with prescribed procedures and resources.
- **Availability** is a measure of the degree to which an item is in the operable state. It is ready to commit at the start of a mission, even when the mission is called for at an unknown (random) point in time. The efficacy of the supply support and maintenance systems as well as the Reliability and Maintainability (R&M) characteristics of the item influences the factor in question.

Contracting for Reliability and Maintainability. An important technique for achieving the R&M goals is to provide meaningful contract incentives in the early stages of the program. From program inception through the EMD phase and into the early stages of production, R&M plans and goals should always be a source selection evaluation factor; and the contracts resulting from the source selection should have incentive clauses related to the levels of R&M achieved and verified. The use of contract warranties is often cost-effective in the production and later stages of the program. However, the operational scenario must be evaluated to determine if warranty conditions are practical. Warranties sometimes impose unrealistic handling, shipping, and data collection demands on the operational user and field maintenance organization, making it difficult to enforce the warranty provisions.

8.7.2 Maintenance Planning Analysis

The contractor generally performs the maintenance planning analysis. The resulting summaries provide maintenance planning information to the government; they may be used to develop initial fielding plans for the end items' support structure. The information contained therein is associated with the repairable items to the level of detail specified on contract. Preventive and corrective maintenance actions should be identified along with required spares and support equipment. Additional supporting information, such as elapsed time of maintenance actions, task frequencies, failure rate, mean times to repair, and man-hour allocations by maintenance action and level, should be required for each item.

8.7.3 Repair Analysis

Emanating from the contractor's maintenance repair analysis, these summaries provide the government with conclusions and recommendations. The contract may ask for actions and recommendations for influencing the system design and a listing of which items should be repaired and discarded. For each item being repaired, they may also identify the level of maintenance to be performed and the associated costs. Further, for the system support structure, they may identify the operational readiness achieved and the placement and allocation of spares, support equipment, and personnel.

The summaries should also provide an explanation of the input data used and their source, the operational scenario modeled, assumptions, constraints, maintenance alternatives considered, the analytical method and model used to perform the economic evaluations, and a discussion of the sensitivity evaluations performed in reaching the summary conclusions and recommendations.

8.7.4 Support and Test Equipment

These summaries provide the government with data necessary to register, or verify the registry of, the support or test equipment in the government's inventory. They may provide details of the Test, Measurement, and Diagnostic Equipment (TMDE) calibration procedures, technical parameters, and any piece of support equipment needed.

8.7.5 Supply Support

These summaries provide the Government with information that may be used to determine initial requirements and cataloging of support items to be procured through the provisioning process. The following data items may be included: identification of the system breakdown, maintenance coding, maintenance replacement factors, overhaul rates, roll-up quantities, design change information, associated technical manuals, long lead items, bulk items, tools, test equipment, etc. These summaries may also allow for review of Provisioning List Item Sequence Number (PLISN) assignment or cross-referencing PLISNs with reference numbers.

8.7.6 Manpower, Personnel, and Training Analysis

These summaries provide information to the Government so that it can establish training plans and ensure manpower and personnel constraints are met. The analysis report should identify the items' corrective and preventive maintenance tasks, operations tasks, manpower estimates for each task by maintenance level, personnel skills required to perform the maintenance tasks, and any training required to allow these tasks to be performed.

8.7.7 Facilities Analysis

These summaries identify the facilities required to maintain, operate, train, and test an item. The facilities may be organizational, intermediate, or depot maintenance training, mobile, and test facilities. The summary information contained within shall help plan for any modification to an existing facility or development of a new facility.

8.7.8 Packaging, Handling, Storage, and Transportation Analysis

These summaries identify the packaging, handling, storage, and transportation requirements. They also provide information relevant to the development of a transportability analysis report.

8.7.9 Postproduction Supportability Analysis

The purpose of these analyses is to review life-cycle support requirements of the new system and associated items prior to closing production lines. These reviews ensure the appropriate support for the system over its remaining life. They identify the potential "weak links" in the future support posture, together with alternative solutions to alleviate those anticipated support difficulties.

8.7.10 Redundancy Analysis

In cases where the design concept involves redundancy to meet reliability requirements, the possible result is improved mission reliability gained. However, this gain may be at the cost of reduced logistics reliability and increased support costs. Attempts should be made to improve single-unit reliability whenever possible to preclude the need for redundancy. As a general rule, the designer should use redundancy in mechanical systems as a last option. However, electronic circuitry is a different matter due to size, weight and complexity considerations. Circuit boards can be designed with spare components installed and a logic to switch from a failed component to a backup spare (even multiple spares in succession) to maintain mission readiness. In this instance, the redundancy can be very cost effective, allowing a potentially complex circuit board to remain in operational use without being compromised by a single point of failure.

8.7.11 Failure Modes and Effects Criticality Analysis (FMECA)

FMECA is an analysis procedure whereby each potential failure mode in a system is analyzed to determine its results or effects on the entire system. The analysis then classifies each potential failure mode according to its severity. It further attempts to identify all single points of failure, i.e., those points where failure of the component can cause failure of the entire system. The results of the FMECA must then be utilized in the design process to reduce the probability of failures through design modification. Single points of failure must be eliminated. The benefits of a FMECA include less initial redesign; reduced scope of the Test, Analyze, Fix, and Test (TAFT) effort; enhanced probability of meeting system cost and schedule goals; and improved customer satisfaction. The Society of Automotive Engineers is in the process of writing a commercial standard covering FMECA guidelines.

For more details, read the *Reliability Toolbook: Commercial Practices Edition*, published by the Reliability Analysis Center, IIT Research Institute, Rome, NY.

8.7.12 Reliability Centered Maintenance Analysis

Reliability Centered Maintenance analysis uses information from FMECA to identify items most critical to system availability. The purpose of the analysis is to develop a scheduled maintenance program with the goal of increasing system availability by identifying failures or potential failures before they degrade system effectiveness. The analysis uses a decision tree as a guide for complete analysis of each significant item. While equipment is in operation, preventive maintenance tasks are identified and scheduled on a routine, periodic basis to prevent failures and, thus, keep the equipment running. Preventive maintenance tasks fall into two subcategories: scheduled inspection and scheduled removal.

For more details, read the *Reliability Toolbook: Commercial Practices Edition*, published by the Reliability Analysis Center, IIT Research Institute, Rome, NY.

8.7.13 Test, Analyze, Fix and Test

TAFT is a disciplined process for systematically detecting and eliminating design weaknesses while simulating the operational environment. TAFT should start with the first article available and continue until requirements are achieved. The process is a closed loop in nature; all detected failures are recorded and analyzed, a redesign effort is undertaken to eliminate the cause of failure, testing is resumed, and the redesign is verified. Based on system requirements and the operating environment, the TAFT plan is normally developed by the contractor.

8.7.14 Failure Reporting, Analysis, and Corrective Action System (FRACAS)

The FRACAS is an adjunct to TAFT, in which all failures and faults (not just those that occur in the operational environment testing) of both hardware and software are formally reported. Analyses are performed to determine the causes of failure, and positive corrective actions are taken.

For more detail, read the *Reliability Toolbook: Commercial Practices Edition*, published by the Reliability Analysis Center, IIT Research Institute, Rome, NY.

8.8 SERVICE-LIFE EXTENSION PROGRAMS

A significant number of systems and/or subsystems have life-limiting characteristics, e.g., metal fatigue (aircraft structures), corrosion, or mechanical wear. Such systems are normally designed and tested for a specified service life, but frequently operational requirements demand an extension of the service life beyond the originally planned date. As plans are laid for extending the service life of the system or subsystem, the program office should consider the formation of an IPT to consider all aspects and impacts of the extension. All of the logistics elements must be analyzed for many of them, such as supply support, maintenance, training, and support equipment, are apt to be affected by the extension.

8.9 FLEXIBLE SUSTAINMENT

Flexible Sustainment (FS) refers to “spares” or “parts.” It includes what “item managers” do as well as activities of system PMs. It can also be defined as the:

- use of performance-based specifications including the
 - use of Form-Fit-Function and Interface (F3I) specifications and the
 - use of nongovernment standards;
- development of innovative, cost-effective life-cycle solutions;
- logical, decision-point-driven process; and
- control of ownership cost by systematically improving reliability.

For further information on flexible sustainment, refer to Chapter 26.

8.10 PROCUREMENT OF TRAINING AND TRAINERS

The Federal Acquisition Streamlining Act of 1994, the Federal Acquisition Reform Act of 1996, and DoDD 5000.1 and DoD 5000.2-R will enable significant changes to DoD’s procurement of training and trainers as well as other logistics elements. Best business practices, tempered by risk and threat assessments, must be used to determine where

outsourcing, privatization, and competition can improve the performance of the training mission. As more commercial items enter the inventory, the program manager and his team must continue to utilize acquisition reforms, privatization, and outsourcing of appropriate training and logistics elements.

The procurement of commercial items as elements of the system adds a new dimension to the determination of training sources. The developers of commercial items are likely to have spawned one or more commercial training sources, which may prove appropriate in meeting the DoD requirement. In a similar vein, each acquisition program should examine opportunities for joint training with other DoD components or allied forces to achieve training goals at reduced cost.

8.10.1 Examples/Tools

The recommended way to develop the performance specifications, and hence to identify needed training requirements, is through the use of a training IPT. The members of the IPT must ensure that they identify the Logistics Management Information (LMI) needed to determine and develop the system operational and maintenance training requirements. The LMI, in turn, must identify what training is needed to operate and maintain the system and what training sources are available. These elements include processes, procedures, techniques, training devices, and equipment used to train civilian and active duty and reserve military personnel to operate and support the system. The types of training should include individual and crew training (both initial and continuation) relative to new equipment and initial, formal, and on-the-job training. These LMI requirements must be identified early in the acquisition process to ensure timely development of a training budget that will satisfy system requirements.

8.10.2 POC/Reference

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